M13/4/CHEMI/HP2/ENG/TZ2/XX/M

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MARKSCHEME

May 2013

CHEMISTRY

Higher Level

Paper 2

24 pages

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Subject Details: Chemistry HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[40 marks]** and **TWO** questions in Section B **[2 x 25 marks]**. Maximum total = **[90 marks]**.

1. A markscheme often has more marking points than the total allows. This is intentional.

2. Each marking point has a separate line and the end is shown by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are underlined are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect).

8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.

10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.

11. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the markscheme. Similarly if the formula is specifically asked for, unless directed otherwise in the markscheme, do not award a mark for a correct name.

12. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the markscheme.

13. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the markscheme.

SECTION A

1. (a) for hemoglobin / myoglobin / transport of oxygen / enzyme / catalase / catalyst; ***[1]***
Allow heme instead of hemoglobin.

(b) systematic (error); ***[1]***
Do not accept parallax.

(c) closeness of agreement of a set of measurements to each other / *OWTTE*; ***[1]***
Allow reproducibility/consistency of measurement / measurements with small random errors/total amount of random errors/standard deviation / a more precise value contains more significant figures / OWTTE.

(d) potassium permanganate has a very dark/deep (purple) colour so cannot read bottom of meniscus / *OWTTE*; ***[1]***

(e) (i) gain (of electrons); ***[1]***

(ii) VII / +7; ***[1]***
Do not accept 7 or 7+.

(f) (i) volume $= 16.80\,(\text{cm}^3) / 18.00 - 1.20\,(\text{cm}^3)$;
amount $\left(= \frac{16.80 \times 5.00 \times 10^{-3}}{1000}\right) = 8.40 \times 10^{-5}\,(\text{mol})$; ***[2]***
*Award **[2]** for correct final answer.*

(ii) $(8.40 \times 10^{-5} \times 5 \times 10) = 4.20 \times 10^{-3}\,(\text{mol per } 250\,\text{cm}^3)$; ***[1]***

(iii) $(55.85 \times 4.20 \times 10^{-3}) = 0.235\,(\text{g})$; ***[1]***
Do not penalize if 56 g mol^{-1} is used for atomic mass of iron.

(iv) $\left(\frac{0.235 \times 100}{1.65} =\right) 14.2\%$; ***[1]***
No ECF if answer >100 %.

(g) (i) *Chemical formula*: MnO_2;
Name: manganese(IV) oxide; ***[2]***
Allow manganese dioxide.
No ECF if formula is incorrect.

(ii) $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$ / $H_2O_2(aq) \rightarrow H_2O(l) + \frac{1}{2}O_2(g)$; ***[1]***
Ignore state symbols.

(iii) add more (sulphuric) acid/H_2SO_4 / ensure enough (sulphuric) acid/H_2SO_4 is present / *OWTTE*; ***[1]***
*Award **[0]** if reference made to HCl or HNO_3.*

(h) (i) NO_3^- and Cl^- anions may also react with $KMnO_4$ / HNO_3 is an oxidizing agent / (HCl will not work as) Cl^- reacts with MnO_4^- (to form Cl_2) / HCl oxidized / *OWTTE*; ***[1]***

For HCl, allow correctly balanced chemical equation:

$2MnO_4^- + 10Cl^- + 16H^+ \rightarrow 2Mn^{2+} + 5Cl_2 + 8H_2O$

Accept NO_3^- and Cl^- may react with $KMnO_4/Fe^{2+}$.

(ii) $CaCO_3(s) + H_2SO_4(aq) \rightarrow CaSO_4(s) + H_2O(l) + CO_2(g)$

correct chemical equation;
correct state symbols; ***[2]***

Allow $CaSO_4(aq)$ instead of $CaSO_4(s)$.
M2 can only be scored if M1 is correct.
*Award **[1max]** if $H_2CO_3(aq)$ is given instead of $H_2O(l) + CO_2(g)$.*

2. (a) minimum energy needed (by reactants/colliding particles) to react/start/initiate a reaction / for a successful collision; ***[1]***

Allow energy difference between reactants and transition state.

(b) k increases with T; ***[1]***

Do not accept k proportional to T or statement of Arrhenius equation from Data booklet.

(c) slope/gradient/$m = \frac{-E_a}{R} / -6.20 \times 10^3$;

Allow range of m from -5.96×10^3 to -6.44×10^3.

Award M1 for $m = \frac{-E_a}{R}$ even if gradient is out of range.

$E_a = (6.20 \times 10^3 \times 8.31) = 51.5\,kJ\,mol^{-1} / 5.15 \times 10^4\,J\,mol^{-1}$

E_a value correct;
units correct; ***[3]***

*Award **[3]** for correct final answer.*
Allow range of E_a from 49.5 to 53.5 kJ mol^{-1}/4.95×10^4 to 5.35×10^4 J mol^{-1}.
Answer must be given correct to three significant figures.
M3 can be scored independently.

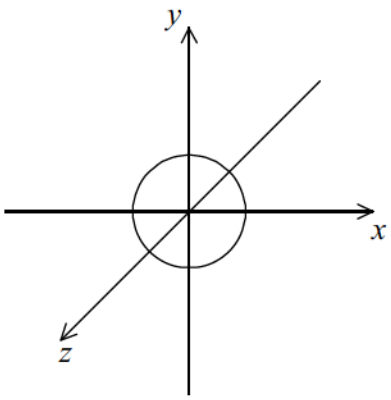
3. (a) ester; ***[1]***

Do not accept just carbonyl.
Allow carboxylato (ligand)/carboxylate (ligand) but not carboxyl/carboxy.

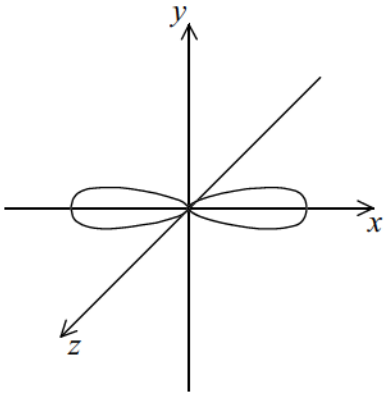
(b) dative (covalent) / coordinate; ***[1]***

Do not allow just covalent or co-dative.

(c) (i)



symmetrical s orbital representation;
Do not penalize if axes are not labelled for s orbital.
x, y, z can be located in any direction.



dumbbell-shaped p_x orbital representation with electron density located along *x*-axis; ***[2]***

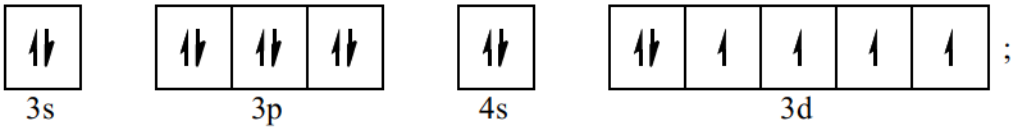
x-axis must be labelled for p_x orbital.
Do not accept if p_y and p_z are also drawn as question asks for orbital not sub-level.

(ii) 16; ***[1]***

(d) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 4d^6$; ***[1]***

Order of 4s and 3d levels can be interchanged.
Do not accept other notation such as subscripts.

(e)



[1]

Allow full arrows instead of half-arrows in orbital diagram.
Sub-levels must be labelled for mark.

4. (a) (i) $(K_c =)\frac{[HI]^2}{[H_2][I_2]} \; / \; \frac{[HI]}{[H_2]^{\frac{1}{2}}[I_2]^{\frac{1}{2}}}$; ***[1]***

Do not award mark if brackets are omitted or incorrect.

(ii)

H_2	$+I_2$	$\rightarrow 2HI$
$(7.50\times10^{-3}-x)$	$(7.50\times10^{-3}-x)$	$2x$ /
$(1.50\times10^{-2}-x)$	$(1.50\times10^{-2}-x)$	$2x$ /
$[H_2]_{initial}-x$	$[I_2]_{initial}-x$	$2x$;

Accept $[H_2]_{initial} = [I_2]_{initial} = 7.50\times10^{-3} (mol\ dm^{-3})$ *for M1.*

$$53 = \frac{(2x)^2}{(7.50\times10^{-3}-x)^2} \; / \; \sqrt{53} = \frac{(2x)}{(7.50\times10^{-3}-x)};$$

Accept $53 = \frac{(2x)^2}{(1.50\times10^{-2}-x)^2} \; / \; \sqrt{53} = \frac{(2x)}{(1.50\times10^{-2}-x)}$.

$[H_2] = 1.62\times10^{-3} (mol\,dm^{-3})$ and $[I_2] = 1.62\times10^{-3} (mol\,dm^{-3})$;

$[HI] = 1.18\times10^{-2}$;

Award ***[4]*** *for correct final answer for values given in M3 and M4.*

Award ***[2 max]*** *for* $[H_2] = [I_2] = 7.50\times10^{-3} (mol\ dm^{-3})$ ***and*** $[HI] = 5.46\times10^{-2} mol\ dm^{-3}$.

OR

if $K_c = \frac{[HI]}{[H_2]^{\frac{1}{2}}[I_2]^{\frac{1}{2}}}$ *is given in (i).*

$\frac{1}{2}H_2$	$+\frac{1}{2}I_2$	$\rightarrow HI$
$(7.50\times10^{-3}-x)$	$(7.50\times10^{-3}-x)$	$2x$ /
$(1.50\times10^{-2}-x)$	$(1.50\times10^{-2}-x)$	$2x$ /
$[H_2]_{initial}-x$	$[I_2]_{initial}-x$	$2x$;

Accept $[H_2]_{initial} = [I_2]_{initial} = 7.50\times10^{-3} (mol\ dm^{-3})$ *for M1.*

$$53 = \frac{(2x)}{(7.50\times10^{-3}-x)};$$

Accept $53 = \frac{(2x)}{(1.50\times10^{-2}-x)}$.

$[H_2] = 2.73\times10^{-4}\,mol\,dm^{-3}$ and $[I_2] = 2.73\times10^{-4}\,mol\,dm^{-3}$;

$[HI] = 1.45\times10^{-2}\,mol\,dm^{-3}$; ***[4]***

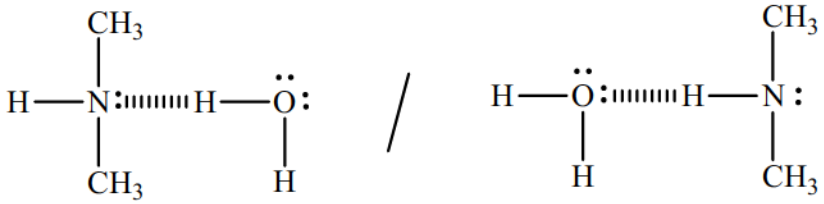
Award ***[4]*** *for correct final answer for values given in M3 and M4.*

Award ***[2 max]*** *for* $[H_2] = [I_2] = 7.50\times10^{-3} (mol\ dm^{-3})$ ***and*** $[HI] = 5.46\times10^{-2} mol\ dm^{-3}$.

(b) van der Waals'/London/dispersion **and** dipole-dipole; ***[1]***
Allow abbreviations for van der Waals' as vdW or for London/dispersion as FDL.

(c) (i) $(CH_3)_2NH$;
(intermolecular) attraction between hydrogen (atom) in O–H/N–H (polar) bond and (lone pair on) electronegative N/O / hydrogen between two very electronegative elements (nitrogen and oxygen) / *OWTTE*; ***[2]***
Accept hydrogen bonded to nitrogen which is electronegative/has lone pair.
Do not allow ECF if M1 is incorrect.

(ii) representative drawing showing hydrogen bond between $(CH_3)_2NH$ and H_2O; ***[1]***



Do not penalize if lone pair as part of hydrogen bond is not shown.
Allow any representation of hydrogen bond (for example, dashed lines, dots etc.) which differs from full stick representation of the other covalent bonds in amine and water molecules.
Allow full line if labelled as hydrogen bond.
Lone pairs on oxygen not necessary.
Award mark if two hydrogen bonds drawn between the molecules from the lone pair and the H on the N.

(iii) N-methylmethanamine / methylmethanamine / dimethylamine; ***[1]***
Do not accept N–N dimethylamine.

SECTION B

5. (a) (i) 2 mol (g) going to 3 mol (g)/increase in number of particles, therefore entropy increases/ΔS positive / *OWTTE*; ***[1]***

Accept if numbers of moles of gas are given below the equation.

(ii) $\left(\Delta S^{\ominus} = [(2)(311.7) + (205.0)] - (2)(325.0) = \right)(+)178.4\ (\text{J K}^{-1}\ \text{mol}^{-1})$; ***[1]***

(iii) heat/enthalpy change/required/absorbed when 1 mol of a compound is formed from its elements in their standard states/at 100 kPa/10^5 Pa/1 bar; ***[1]***

Allow $1.01 \times 10^5\ Pa / 101 kPa / 1 atm$.

Allow under standard conditions or standard temperature and pressure. Temperatures not required in definition, allow if quoted (for example, 298 K/ 25 °C – most common) but pressure value must be correct if stated.

(iv) $\left(\Delta H^{\ominus} = [(2)(-288.1)] - [(2)(-542.2)]) = \right)(+)508.2\ (\text{kJ mol}^{-1})$; ***[1]***

(v) $\left(\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus} = (508.2) - (298)\left(\frac{178.4}{1000}\right) = \right)(+)455.0\ (\text{kJ mol}^{-1})$; ***[1]***

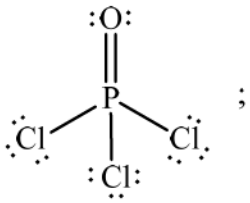
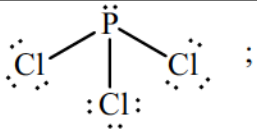
(vi) $T > \left(\frac{\Delta H^{\ominus}}{\Delta S^{\ominus}} = \frac{508.2}{\left(\frac{178.4}{1000}\right)} = \right) 2849\ (\text{K}) / 2576\ (^{\circ}\text{C})$; ***[1]***

Allow temperatures in the range 2848–2855 K.

Accept $T = 2849 (K)$.

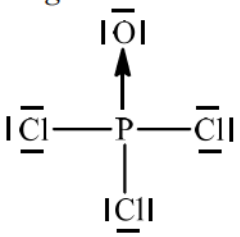
No ECF for temperatures T in the range 0–100 K.

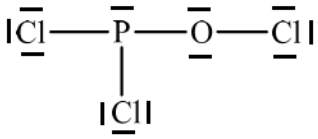
(b) (i)

	$POCl_3$	PCl_3
Lewis (electron dot) Structure	 ; *Accept legitimate alternatives for $POCl_3$ as shown below*.*	 ;
	Allow any combination of dots/crosses or lines to represent electron pairs. *Penalise missing lone pair on P in PCl_3 but penalize missing lone pairs once only on terminal O or Cl atoms.*	
Shape	tetrahedral;	trigonal/triangular pyramidal; *Do not allow tetrahedral.* *Do not allow just pyramidal.*
	Do not allow ECF from Lewis structures with incorrect number of negative charge centres. *Only allow shapes based on legitimate structures below.*	

[4]

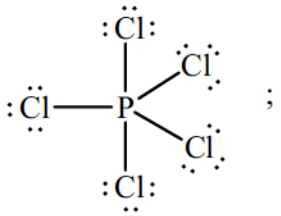
**Legitimate alternatives for $POCl_3$:*





(ii) allow any bond angle in the range 100° to less than 109° (experimental value is 100°);
due to four negative charge centres/four electron pairs/four electron domains (one of which is a lone pair)/tetrahedral arrangement of electron pairs/domains;
extra repulsion due to lone pair electrons / lone pairs occupy more space (than bonding pairs) so Cl–P–Cl bond angle decreases from 109.5° / *OWTTE*; ***[3]***

(iii) $PCl_3(l) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HCl(aq)$; ***[1]***
Ignore state symbols.
Do not accept $P(OH)_3$ for H_3PO_3.

(c) (i)  ; **[1]**

Allow any combination of dots/crosses or lines to represent electron pairs.
Do not penalise missing lone pairs on Cl if already penalised in (b)(i).

(ii) trigonal/triangular bipyramidal; **[1]**
Do not allow ECF from Lewis structures with incorrect number of negative charge centres.

(iii) 120° **and** 90°/180°; **[1]**
Ignore other bond angles such as 240° and 360°.
Apply list principle if some correct and incorrect angles given.

(iv)

	Isomer 1	Isomer 2	Isomer 3
Structure	both Br's in axial positions, all Cl's in equatorial positions	both Br's in equatorial positions, two Cl's in axial positions, one Cl in equatorial position	one Br in equatorial position, one Br in axial position, one Cl in axial position and two Cl's in equatorial positions
Molecular polarity	non-polar	polar	polar

[3]

*Award **[1]** for correct structure **and** molecular polarity.*
*Award **[1 max]** for correct representations of all three isomers.*
Lone pairs not required.

(d) (i) species with lone/non-bonding pair (of electrons);
which bonds to metal ion (in complex) / which forms dative (covalent)/coordinate bond to metal ion (in complex); **[2]**

(ii) unpaired electrons in d orbitals / d sub-level partially occupied;
d orbitals split (into two sets of different energies);
frequencies of (visible) light absorbed by electrons moving from lower to higher d levels;
colour due to remaining frequencies / complementary colour transmitted; **[3max]**
Allow wavelength as well as frequency.
Do not accept colour emitted.

6. (a) $[H_3O^+] = \frac{K_w}{[OH^-]} = \frac{(1.00\times10^{-14})}{(3.98\times10^{-3})} = 2.51\times10^{-12}\,(\text{mol dm}^{-3})$;

$\text{pH}\left(= -\log[H_3O^+] = -\log(2.51\times10^{-12})\right) = 11.6$; ***[2]***

OR

$\text{pOH} = \left(-\log(5.98\times10^{-3}) =\right) 2.4$;

$\text{pH} = (14.00 - 2.40) = 11.6$;

*Award **[2]** for correct final answer.*
Allow correct use of H^+ instead of H_3O^+ throughout.

(b) (i) *Brønsted-Lowry theory:*
proton/H^+ donor;

Lewis theory:
electron pair acceptor; ***[2]***

(ii) *Strong acid:* acid/electrolyte (assumed to be almost) completely/100% dissociated/ionized (in solution/water) / *OWTTE* **and** *Weak acid:* acid/electrolyte partially dissociated/ionized (in solution/water) / *OWTTE*; ***[1]***

(c) (i)

Mixture	Buffer
HCOOH and KHCOO	Yes
HCl and excess NH_3	Yes;

[1]

*Award **[1]** for both "yes".*
*Award **[0]** for any "no".*

(ii) $K_a = \frac{[H_3O^+][X^-]}{[HX]} \;/\; [H_3O^+] = \frac{K_a[HX]}{[X^-]}$;

$[H_3O^+] = \frac{1.40\times10^{-4}\times1.55\times10^{-1}}{1.05\times10^{-1}}$;

$[H_3O^+] = 2.07\times10^{-4}\,(\text{mol dm}^{-3})$;

$\text{pH}\left(= -\log(2.07\times10^{-4})\right) = 3.68$;

OR

$\text{p}K_a = 3.854$;

$\text{pH} = \text{p}K_a + \log\frac{[X^-]}{[HX]} \;/\; \text{pH} = \text{p}K_a - \log\frac{[HX]}{[X^-]}$;

$\text{pH} = 3.854 - 0.169$;

$\text{pH} = 3.68$; ***[4]***

*Award **[4]** for correct final answer.*
Allow correct use of H^+ instead of H_3O^+ throughout.
Allow acid for HX, conjugate base/salt for X^- throughout.

(d) (i) $HIn(aq) \rightleftharpoons H^+(aq) + In^-(aq)$ / $HIn(aq) + H_2O(l) \rightleftharpoons In^-(aq) + H_3O^+(aq)$;
Colour A Colour B Colour A Colour B

Allow statement such as solution of weak acid with different colours for conjugate base/$In^-(aq)$ ***and*** *undissociated acid/HIn(aq) / OWTTE.*
Equilibrium sign required.
Ignore state symbols.
Allow corresponding argument for an indicator as a weak base.
for example, $BOH(aq) \rightleftharpoons B^+(aq) + OH^-(aq)$ etc.

in acid/presence of H^+ equilibrium lies to left (so colour A);
in alkali/base/presence of OH^- equilibrium lies to right (so colour B);
colour changes/end point when $[HIn(aq)] \approx [In^-(aq)]$; ***[3 max]***

(ii) phenolphthalein/phenol red;
indicator changes colour in range of pH at equivalence point which is above 7 / *OWTTE*; ***[2]***
M2 can be scored independently even if indicator is incorrect.
Accept it is a titration of weak acid with a strong base for M2.

(iii) $n(HCl)\left(=\frac{(150\times5.00\times10^{-1})}{(1000)}\right) = 7.50\times10^{-2}(mol)$ **and**
$n(NaOH)\left(=\frac{(300\times2.03\times10^{-1})}{(1000)}\right) = 6.09\times10^{-2}(mol)$;
$n(HCl)_{remaining}(=(7.50-6.09)\times10^{-2}) = 1.41\times10^{-2}(mol)$;
$[HCl] = (1.41\times10^{-2})(1000)/(450) = 3.13\times10^{-2}(mol\,dm^{-3})$;
$pH = 1.50$; ***[4]***
Award ***[4]*** *for correct final answer.*
Award ***[3max]*** *for $pH = -\log(1.41\times10^{-2}) = 1.85$.*

(e) (i) *$FeCl_3$:*
acidic;
Fe^{3+} ion attracts electrons in OH bonds of water ligands releasing H^+ ions (due to high charge density) / *OWTTE*;
Accept suitable equations such as $[Fe(H_2O)_6]^{3+} \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+} + H^+$ / $[Fe(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+} + H_3O^+$ *for M2.*
Accept equations indicating the formation of $[Fe(H_2O)_4(OH)_2]^+$, $[Fe(H_2O)_3(OH)_3]$, $[Fe(H_2O)_2(OH)_4]^-$.
Do not penalize →.
M2 can only be awarded if M1 correct.

$CH_3CH_2NH_3NO_3$:
acidic;
$CH_3CH_2NH_3^+$ is conjugate acid of weak base, $CH_3CH_2NH_2$ so acidic and NO_3^- is conjugate base of strong acid, HNO_3, so pH-neutral / salt of a weak base and a strong acid / *OWTTE*; ***[4]***
M4 can only be awarded if M3 correct.
Do not allow the salt produces a strong acid and weak base in solution.

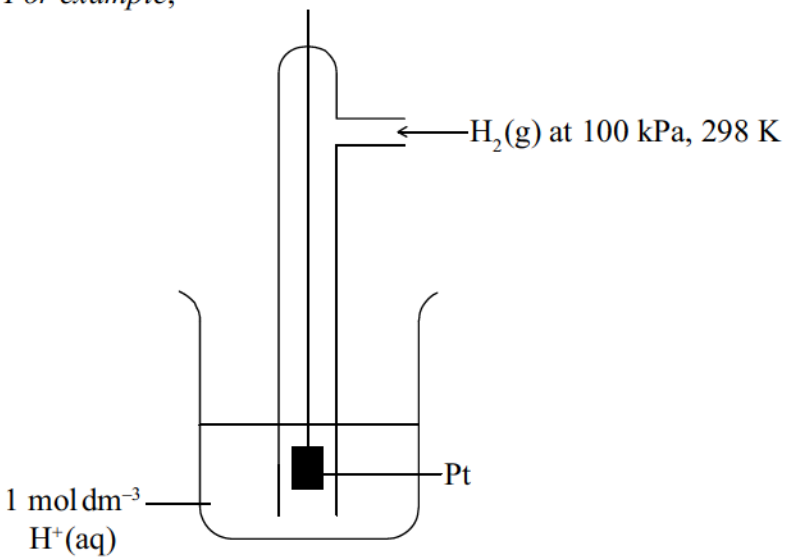
(ii) acidic;
$K_a(NH_4^+) > K_b(F^-)$ / $pK_a(NH_4^+) < pK_b(F^-)$; ***[2]***
M2 can only be awarded if M1 correct but award ***[1max]*** *for neutral as salt of weak acid and weak base.*

7. (a) increase (in oxidation number); ***[1]***

(b) (i) $Cu(s)+2NO_3^-(aq)+4H^+(aq) \rightarrow Cu^{2+}(aq)+2NO_2(g)+2H_2O(l)$ /
$Cu(s)+2HNO_3(aq)+2H^+(aq) \rightarrow Cu^{2+}+2NO_2(g)+2H_2O(l)$;
correct reactants and products;
fully balanced chemical equation; ***[2]***
Ignore state symbols.
M1 can be scored if there are unbalanced electrons in equation.
M2 can only be scored if M1 is correct.
M2 can be scored if there are balanced electrons on both sides of equation.

(ii) *Oxidizing agent:* NO_3^-/nitrate/HNO_3/nitric acid **and** *Reducing agent:* Cu/copper; ***[1]***

(c) (i) Diagram showing gas, solution and solid electrode;
For example,



1 mol dm^{-3} $H^+(aq)$ and Pt;
Allow 1 mol L^{-1} or 1 M.
Allow 1 mol dm^{-3} HCl (aq) or other source of 1 mol dm^{-3} $H^+(aq)$ ions.

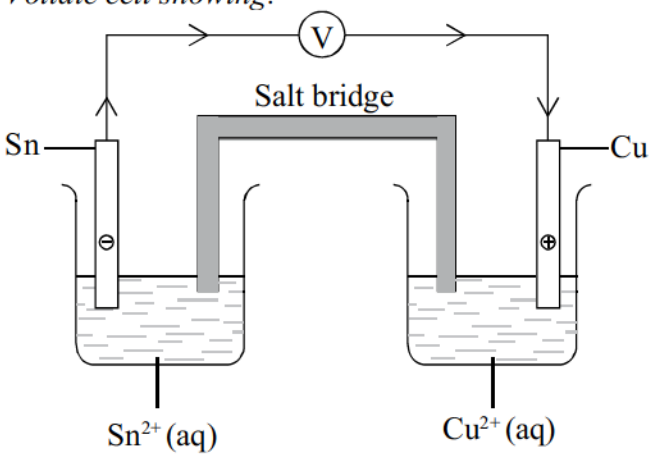
100 kPa/10^5 Pa/1 bar ($H_2(g)$ pressure) **and** 298 K / 25 °C; ***[3]***
Ignore state symbols throughout.
Allow 1.01×10^5 Pa/1 atm.

(ii) potential of reduction half-reaction under standard conditions measured relative to standard hydrogen electrode/SHE / potential under standard conditions relative to standard hydrogen electrode/SHE; ***[1]***
Instead of standard conditions allow either solute concentration of 1 mol dm^{-3} or 100 kPa/10^5 Pa/1 bar (pressure) for gases (allow 1 atm).
Allow voltage/EMF instead of potential.

(iii) $Cu^{2+}(aq) + H_2(g) \rightarrow Cu(s) + 2H^+(aq)$

reactants and products;
fully balanced chemical equation, including state symbols; ***[2]***
M2 cannot be scored if M1 is incorrect.

(d) (i) *Voltaic cell showing:*



Labelled positive electrode (cathode): Cu^{2+}/Cu **and** *negative electrode (anode):* Sn^{2+}/Sn ;
Do not penalize if state symbols are not included (since given in question).

voltmeter and salt bridge;
Voltmeter can be labelled or drawn as a circle with a V.
Allow ammeter/A.
Salt bridge can be labelled, represented with drawing connecting the two half-cells, labelled as potassium nitrate or using its chemical formula (for example, KNO_3) etc.

correct direction of electron movement from Sn to Cu in external circuit; ***[3]***

(ii) (+) 0.48 (V); ***[1]***

(e) (i) positive; ***[1]***

(ii) provides ions (to carry current) / water poor conductor (of electricity); ***[1]***
Do not accept electrons instead of ions.

(iii) copper reacts so (nonreactive metal such as) Pt used; ***[1]***
Accept Ag, Au or any named metal less reactive than copper as electrode.
Do not accept Cu reacts with water or graphite as electrode.

(iv) *Positive electrode (anode):*
$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ / $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$;

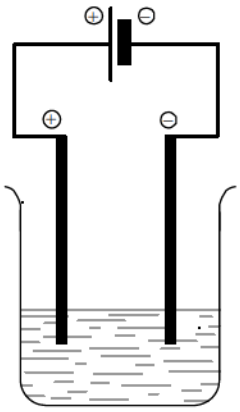
Negative electrode (cathode):
$H^+(aq) + e^- \rightarrow \frac{1}{2}H_2(g)$ / $4H^+(aq) + 4e^- \rightarrow 2H_2(g)$ / $2H^+(aq) + 2e^- \rightarrow H_2$ /
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ / $H_2O(l) + e^- \rightarrow \frac{1}{2}H_2(g) + OH^-$; ***[2]***
*Award **[1 max]** if M1 and M2 reversed.*

Ignore state symbols.
Allow e instead of e^-.
Do not penalize use of equilibrium sign instead of $\rightarrow$.
Accept a multiple of the equations.

(v) $2H_2O(l) \rightarrow 2H_2(g) + O_2(g) / H_2O(l) \rightarrow H_2(g) + \frac{1}{2}O_2(g)$; ***[1]***

State symbols required as asked for in question.
Do not penalize use of equilibrium sign instead of $\rightarrow$.
Do not accept any multiple of $2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2(g) + O_2(g)$.

(vi)



electrolytic cell showing solid electrodes immersed in solution;
positive electrode (anode) connected to positive terminal of battery **and**
negative electrode (cathode) to negative terminal; ***[2]***
Allow graphite or metal given in e(iii) as electrodes.

(vii) bubbles /gas produced; ***[1]***
Do not accept hydrogen is formed at cathode and oxygen formed at anode.

(f) $n(O_2)\left(=\left(\frac{100}{22.4\times1000}\right)\right) = 4.46\times10^{-3}(\text{mol})$;

$m\left(=(4.46\times10^{-3}\times2\times207.19)\right) = 1.85(\text{g})$;

OR

$n(O_2)\left(=\frac{PV}{RT}\right) = 4.45\times10^{-3}(\text{mol})$;

$m\left(=4.45\times10^{-3}\times2\times207.19\right) = 1.84(\text{g})$; ***[2]***

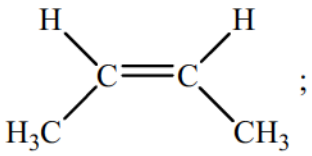
8. (a) compounds with same structural formula but different arrangements of atoms in space; ***[1]***
*Award **[1]** if correct description of geometric **and** optical isomers given.*

(b) **1**: sp^2 **and 2**: sp^3 ; ***[1]***

(c) amine;
benzene ring;
Allow phenyl (group).
Do not allow just benzene.

alkene / chloroalkene;
chloro;
ether / phenyl ether; ***[1 max]***
Ethers not required as per guide but allow if given.

(d) (i)



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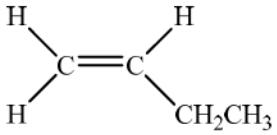

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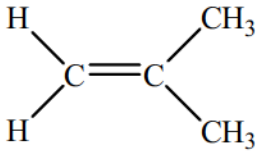

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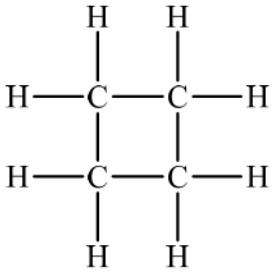

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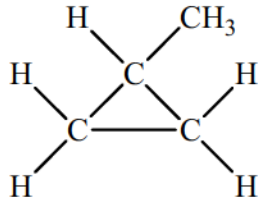


;

[2 max]

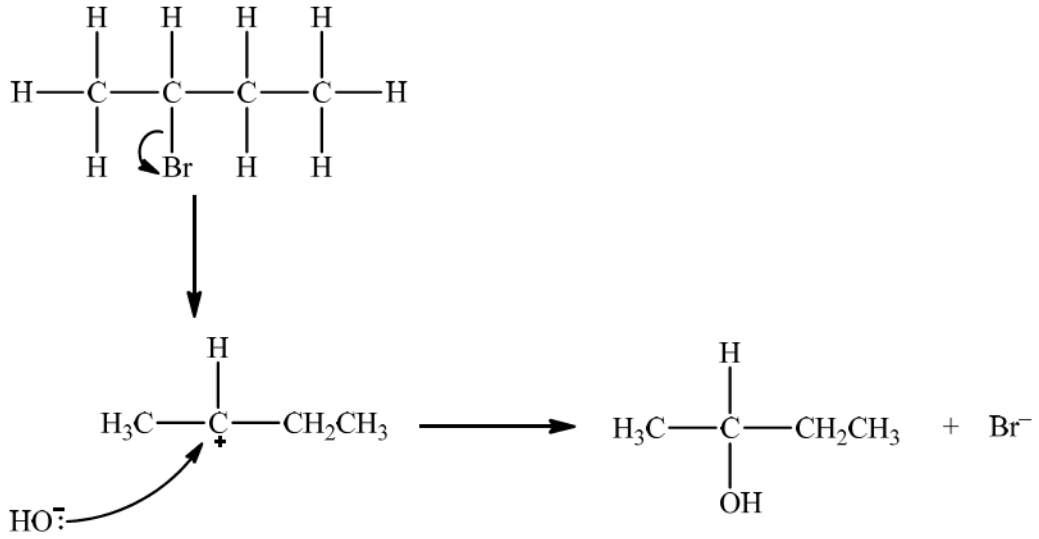
(ii) *trans*-but-2-ene **and** *cis*-but-2-ene;
Allow trans 2-butene and cis 2-butene.
Do not accept just 2-butene or 2-butene.

but-1-ene; ***[2]***
Allow 1-butene.

(iii) **Q:** $CH_3CHBrCH_2CH_3$;
R: $CH_3CH(OH)CH_2CH_3$;
S: $CH_3CHBrCHBrCH_3$;
T: $CH_3CH(OH)CH_2CH_3$; ***[4]***
Condensed or full structural formulas may be given.

(iv) *Since secondary bromoalkane could be either S_N1 and S_N2 so allow S_N1 or S_N2 for M1 –M4.*

S_N1:



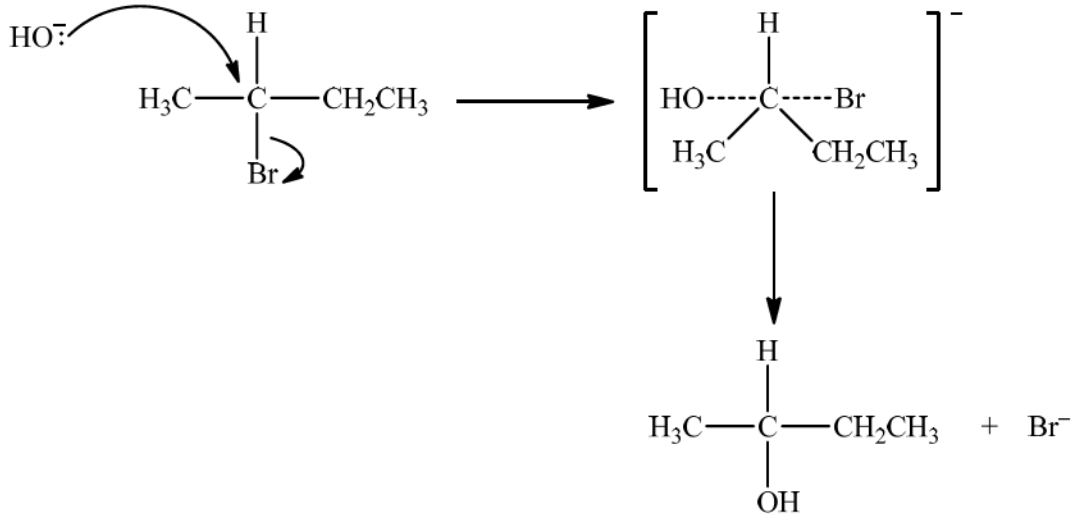
curly arrow showing Br leaving;
Do not allow arrow originating from C to C–Br bond.

representation of secondary carbocation;
curly arrow going from lone pair/negative charge on O in HO^- to C^+;
Do not allow arrow originating on H in OH^-.

formation of $CH_3CH(OH)CH_2CH_3$ **and** Br^-;
Allow formation of NaBr instead of Br^-.

OR

S_N2:



curly arrow going from lone pair/negative charge on O in HO^- to C;
Do not allow curly arrow originating on H in OH^-.

curly arrow showing Br leaving;
Accept curly arrow either going from bond between C and Br to Br in 2-bromobutane or in the transition state.
Do not allow arrow originating from C to C–Br bond.

representation of transition state showing negative charge, square brackets and partial bonds;
Do not penalize if HO and Br are not at 180° to each other.
Do not award M3 if OH—C bond is represented.

formation of $CH_3CH(OH)CH_2CH_3$ **and** Br^-; ***[4]***
Allow formation of NaBr instead of Br^-.

(v) $H_3CCOCH_2CH_3$; ***[1]***
Condensed or full structural formula may be given.

(vi) butan-2-one; ***[1]***
Allow 2-butanone or butanone.
Accept butan-2-one if (v) is incorrect but also apply ECF.

(e) (i) $m_C : (1.755\times10^{-1}\times12.01)/(44.01) = 4.790\times10^{-2}\,g$ **and**
$m_H : (7.187\times10^{-2}\times2\times1.01)/(18.02) = 8.056\times10^{-3}\,g$;
$m_O : (6.234\times10^{-2} - 8.056\times10^{-3} - 4.790\times10^{-2}) = 6.384\times10^{-3}\,g$;
($n_C = 3.988\times10^{-3}$ **and** $n_H = 2\times3.988\times10^{-3}$ and $n_O = 3.988\times10^{-3}$ hence empirical formula $=) C_{10}H_{20}O$;
$\left(M(C_{10}H_{20}O) = 156.30\ (g\,mol^{-1})\right.$, therefore molecular formula $=\left.\right)\ C_{10}H_{20}O$;

OR

$n_{CO_2} = \left(\frac{1.755\times10^{-1}}{44.01}\right) = 3.988\times10^{-3}$ **and** $n_{H_2O} = \left(\frac{7.187\times10^{-1}}{18.02}\right) = 3.988\times10^{-3}$;
$m_O : (6.234\times10^{-2} - 8.056\times10^{-3} - 4.790\times10^{-2}) = 6.384\times10^{-3}\,g$;
($n_C = 3.988\times10^{-3}$ **and** $n_H = 2\times3.988\times10^{-3}$ and $n_O = 3.988\times10^{-3}$ hence empirical formula $=) C_{10}H_{20}O$;
$\left(M(C_{10}H_{20}O) = 156.30\ (g\,mol^{-1})\right.$, therefore molecular formula $=\left.\right) C_{10}H_{20}O$; ***[4]***

Allow alternative working to be used.
*Award **[3 max]** for $C_{10}H_{20}O$ if no working shown.*

(ii) chiral (carbon/centre/atom) / (tetrahedral) carbon surrounded by four different groups; ***[1]***
Accept chiral compound or chiral molecule.

(iii) polarimeter **and** (enantiomers) rotate plane of polarized light in (equal and) opposite directions; ***[1]***

(iv) *Physical properties:*
identical except for rotation of plane polarized light;
Accept "identical" as different optical properties assessed in (iii).
Do not accept similar.
Chemical properties:
identical unless they interact with other optically active/chiral compounds/reagents/solvents / identical with achiral compounds/reagents /solvents / *OWTTE*; ***[2]***
Allow different physiological effects/taste.